I. C. 6726

JUNE, 1933

DEPARTMENT OF COMMERCE

UNITED STATES BUREAU OF MINES
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SAFETY PRACTICES IN TUNNELING OPERATIONS AT THE HETCH HETCHY WATER-SUPPLY PROJECT, CITY AND COUNTY OF SAN FRANCISCO, CALIF.

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S. H. ASH AND C. R. RANKIN

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SAFETY PRACTICES IN TUNNELING OPERATIONS AT THE HETCH HETCHY WATER-SUPPLY PROJECT, CITY AND COUNTY OF SAN FRANCISCO, CALIF.[1]

By S. H. Ash[2] and C. R. Rankin[3]

PURPOSE OF REPORT

Tunnel driving is recognized as one of the most hazardous of occupations; this is a reflection of the high accident severity rates and resultant high compensation and similar costs in this industry. Most tunnels are driven by contractors who bid for the jobs, taking into consideration the prevailing industrial insurance rates at the time the bids are placed. After the bid is secured the contractor then attempts to complete the job at the minimum cost to himself. In a sense the accident-cost item is fixed for at least one year when a policy is secured. Time is generally an important factor not only for the contractor, but also for the insurance carrier and the assured. If the assured represents a private interest, the cost burden usually is ultimately placed on the general public which avails itself of the service contemplated; if the project is a governmental enterprise the cost burden unquestionably falls upon the general public involved and on the general tax payer. For these reasons it is of vital interest to the public that accidents not only be kept at a minimum as a humanitarian objective, but also because the accident-cost burden, too frequently not even realized and considered to the degree that it should be, can assume proportions that materially affect the cost of the enterprise.

The basic industrial insurance rate for tunneling in California in 1932 contemplated an earned premium of 12.12 percent of the labor pay roll. The State has been particularly engaged in large construction enterprises, some of which involve high accident cost rates, notably structural-steel bridge building, which contemplates an earned premium of 19.65 percent of the labor pay roll. When this figure is compared with the much lower rates that apply to other industries it is apparent that a heavy toll in human wreckage is taken by such engineering projects, which must be viewed as monuments to human suffering as well as to human achievement.

This report purposes to show the methods followed at the Hetch Hetchy water-supply project, whereby accidents and their resultant suffering and cost have been minimized because safety has been given a prominent place. Costs in this particular project which will ultimately be paid by the public at large in the district served have been particularly emphasized. The data given are based upon the experience in the Hetch Hetchy tunnels constructed by the forces of the city and county of San Francisco, and cover the period from October 1, 1920, to September 30, 1931, inclusive, during which the compensation insurance item of the industrial insurance cost has been carried with the State compensation insurance fund. The data given in the report should have value to those interested in the relationship of tunneling operations to accident occurrence and accident costs.

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[1] – The Bureau of Mines will welcome reprinting of this paper, provided the following footnote acknowledgment is used: "Reprinted from U.S. Bureau of Mines Information Circular 6726."

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The tunneling was done through ground that is representative of strata of almost any conceivable type, from the hard, massive granites of the high Sierras, through the metamorphics of the foothills, to the exceedingly gassy, water-laden, heavy, and highly fractured ground of the Coast Range.

The management of the enterprise from its beginning was under the direct charge of M. M. O'Shaughnessy, city engineer, assisted by L. T. McAfee, chief assistant engineer, and P. J. Ost, electrical engineer. The field work was done under the supervision of C. R. Rankin, construction engineer, and his corps of assistants.

ACKNOWLEDGMENTS

In the preparation of this report the writers are indebted to M. M. O'Shaughnessy, city engineer, and L. T. McAfee, chief assistant on public utilities, whose permission and assistance made the report possible. They also acknowledge the assistance and cooperation of C. H. Fry, superintendent of safety, and Fred L. Lowell, chief mining engineer, of the Industrial Accident Commission; of Frank J. Creede, manager; of J. J. Gallagher, secretary of the State Compensation Insurance Fund, in furnishing data relative to accident experience and accident costs; and of A. J. Wehner, safety engineer at the Coast Range division.

THE HETCH HETCHY WATER-SUPPLY PROJECT

The Hetch Hetchy Water-Supply Project of the city and county of San Francisco had its beginning in 1901, but nothing could be definitely done until 1908, when a bond issue was voted which provided for the purchase of watershed lands and water rights. Actual construction work began in July, 1914. The burden of responsibility of carrying to its completion a project, the benefits of which cannot be measured at this time nor will be realized until long after its labors are forgotten, has been largely the task of M. M. O'Shaughnessy, city engineer.

The project is expected ultimately to furnish about 400 million gallons of water daily to 4,000,000 people in the San Francisco peninsula and to develop about 250,000 hydroelectric horsepower for general use for such purposes as household lighting, heating, railway operation, and manufacturing.

The melting snows of the Sierra Nevada are caught and stored in two reservoirs, Hetch Hetchy and Lake Eleanor. Water released from Hetch Hetchy flows 12 miles down the Tuolumne Canyon to unite with the water from Lake Eleanor at Early Intake. Here a dam turns the water into an aqueduct which will conduct it 155 miles to San Francisco, all by gravity - no pumping, and nowhere expose it to contamination. The aqueduct will consist of 82 miles of tunnel 10 feet 3 inches in diameter, and 73 miles of large steel pipes. Hydroelectric power is developed by dropping the water from the high mountain levels to the lower levels. On May 1, 1932, there remained but 4.74 miles, or 0.58 percent, of the tunnel to be driven.

It is beyond the scope of this report even briefly to describe the many problems and details of construction of this notable project.

Its final completion is now a matter of months. A complete description of the problems and progress of the work is contained in the various reports[4] [5] [6] of the Bureau of Engineer-

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4 – O'Shaughnessy, M. M., Reports of the Bureau of Engineering, Department of Public Works, City and County of San Francisco, 1908–1931, inc.

5 - O'Shaughnessy, M. M., Hetch Hetchy Water Supply: Bureau of Public Works Bull , Oct. 1925, 47 pp.

6 – O'Shaughnessy, M. M., Hetch Hetchy Project: Apr. 1930, 8 pp.

ing of the City and County of San Francisco. The construction work[7] has been described in part, and recent safety problems[8] [9] [10] and practices emphasized in some technical publications.

Particular interest is manifest at this time in costs, including accident costs at all enterprises and particularly those involving public expenditures. If the basic industrial insurance rate for tunneling can be taken as a criterion of the real hazards in the industry, then tunneling is a more hazardous occupation than mining, as it carries a higher rate; hence, those who are interested in tunneling operations should try by a careful study to ascertain why accident-cost rates for tunneling are higher than for mining when mining is largely tunneling and is often carried on under conditions more inherently hazardous than in actual tunnel construction.

Some hazards of mining which have been encountered in tunneling at the Hetch Hetchy project have received much publicity; the Coast Range division in particular has encountered a methane-gas occurrence in these tunnels such as undoubtedly has never been encountered elsewhere over such distances in tunneling operations in the history of the nation. The methane released per square foot of area opened equals and in some sections exceeds that found in the gassy coal mines of our country. The safety measures that have been adopted, including those for safeguarding against the explosive gas, are not usually found to a similar degree in the majority of our coal mines; hence a brief description is given of the tunnels in the project.

HETCH HETCHY TUNNELS

Aqueduct Tunnel, Mountain Division

The mountain division of the aqueduct, which embraces the Early Intake diversion dam and the aqueduct tunnel to Priest Reservoir, has been conveying an average flow of 735 second-feet of 475 million gallons daily since August 14, 1925, when the Moccasin power plant started generating electrical energy. The tunnel, starting at an elevation of 2,326 feet, is 18.8 miles long and ends at Priest Reservoir at an elevation of 2,170 feet. The easterly 7.5 miles, in hard granodiorite, is 13 feet 4 inches by 13 feet 6 inches in width and height and is not lined. The balance (11.3 miles) is lined with concrete to a horseshoe section of 10 feet 3 inches diameter. Rock encountered consisted of diorite, quartzite, slate, and amphibole schist. The tunnel has a grade of 8 feet per mile. Two shafts were constructed totaling 1,432 feet in depth.

Excavation was prosecuted from 12 working faces; the first heading was begun on July 7, 1917, and the last connection in tunnel driving was made on November 26, 1923. Tunnel lining (60,630 feet) was begun on March 20, 1923, and was completed in May, 1925.

Aqueduct, Foothill Division

The foothill division of the aqueduct is 16.7 miles in length and extends from the tail race of the Moccasin power house (elevation 881 feet) to the Oakdale portal at the eastern edge of the San Joaquin Valley (elevation 747 feet), which is the beginning of the 47.5-mile pipe line connecting with the Tesla portal, the beginning of the Coast Range tunnels.

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[7] — Engineering News-Record, Construction Progress on Hetch Hetchy Aqueduct: Vol. 100, 1928, pp. 614-616; Progress on Hetch Hetchy Water-Supply Tunnels: Vol. 102, 1929, p. 171; Hetch Hetchy Tunnel Construction: Vol. 106, 1931, pp. 96-100.

[8] — Harrington, D., Progress in Metal-Mine Ventilation in 1930: Inf. Circ. 6469, Bureau of Mines, 1931, pp. 5-12.

[9] — Jarrett, S. M., Safety Progress on the Hetch Hetchy Aqueduct: Nat. Safety News, March, 1932, p. 21.

[10] — Ash, S. H., and Rankin, J. H., Permissible Electric Cap Lamps and Ventilation in Certain California Mines and Water-Tunnel Construction: Bull. 359, Bureau of Mines, 1932, 36 pp.

The foothill tunnels were started in February 1926. All work was done by day labor with city forces until the fall of 1926, when two contracts were awarded for carrying out certain portions of the work. The tunneling and lining operations were completed in October 1929. The total length of the tunnels in this division is 83,663 feet (as excavated) or 15.85 miles, of which 36,887 feet were excavated by contractors and 46,776 feet by city forces under the direction of the city engineer. Of the 83,663 feet of tunnel driven, 43,176 feet were lined and 40,487 feet unlined. Of the 43,176 feet lined, 30,732 feet were lined by city forces and 12,444 feet by contractors. The accident experience of the contractors is not available and is not included in this report.

San Francisco Bay Division

The San Francisco bay division is a section of the aqueduct, 21 miles long, completed from Irvington at the west portal of the Coast Range tunnels, and brings additional water from Alameda County pending completion of the Coast Range tunnels. Included in this division is the Pulgas Tunnel, the west end of the development, near Crystal Springs Reservoir. This tunnel was completed in May 1924, is 8,676 feet long, has a diameter of 10 feet 3 inches, of horseshoe section, and is concrete lined. All but 240 feet required timbering. The work was done by contract, and the accident-cost experience is not included in this report.

Aqueduct Tunnel, Coast Range Division

The Coast Range division of the aqueduct was just getting under way at the beginning of 1928, and is to extend from the Tesla portal at an elevation of 399 feet, to the Irvington portal, at an elevation of 316 feet; this is the remaining intervening section to be completed between the San Joaquin Valley pipe line and the San Francisco Bay division. The valley of Alameda Creek, which will be crossed by a pipe line 0.6 mile in length, divides the Coast Range tunnel into two sections, which are 25.1 miles and 3.4 miles long. The short section of 3.4 miles on the Irvington end has been driven, and the work of concrete-lining its entire length is nearing completion.

The 25.1-mile tunnel is worked from two portals and five shafts, being thus divided into six sections. On March 4, 1931, excavation was completed in the Tesla portal-Thomas shaft section, a distance of 4.4 miles, and the concrete lining for the entire distance is nearing completion. The longest and most difficult section lies between the Mocho shaft and Mitchell shaft, a distance of 5.2 miles, which should be completed by the close of 1933. Excavation between the Mocho and Valle shafts was completed May 13, 1932.

Of the total 151,227 feet (28.64 miles revised distance) of tunnel in the Coast Range division, 126,196 feet had been driven by May 1, 1932, which left 25,031 feet, or 4.74 miles only, to be driven, - only 16.55 percent of the total length of the Coast Range tunnels. During the fiscal year July 1, 1930, to June 30, 1931, a distance of 7.2 miles was driven. The driving of the Coast Range tunnels has been done entirely by San Francisco City forces.

Extraordinarily difficult conditions have been encountered in the driving of the Coast Range tunnels, which are to be concrete-lined for their entire length. These difficulties have been numerous and of varied character: Swelling ground has been encountered that requires considerable retimbering until a type of concreting designated as guniting has been done; quicksand and water have contributed their share in retarding normal progress in places; the unusual prevalence of large amounts of the explosive gas methane, which causes so much trouble in coal mines, has necessitated the adoption of such explosion preventive measures as regards equipment, ventilation, and supervision as are seldom found even in gassy coal mines and not at all in the usual tunneling operations; and occurrences of hydrogen sulphide gas have been encountered, but have been successfully handled by increased ventilation and care. That the safety precautions adopted have accomplished results is unquestionably shown by a study of the statistics included in this report. A disastrous explosion such as could, and very likely would, result if adequate precautions were not taken, would not only cause loss of life, but probably also cause enormous property damage in the section involved. To avert these possible catastrophes, too often accepted as hazards of the industry, the city engineers, the State Industrial Accident Commission, and engineers of the United States Bureau of Mines have cooperated in a constructive endeavor to safeguard the workmen, which has been eminently successful. It is of interest to know the nature and results of the safety practices that are in effect at present with the sole purpose of preventing accidents and disasters. The particular data reported here reflect the experience in the Coast Range tunnels. It is with the tunneling operations of this section of the aqueduct that the remaining descriptive matter in this report deals primarily.

OPERATING FEATURES, COAST RANGE DIVISION

Size of Operations

Because of proximity to the Bay region around San Francisco the operations of the Coast Range division have assisted materially in relieving unfavorable conditions in this area during the present depression by maintaining a large pay roll and demand for materials. The pay roll in the tunneling operations alone was over two and a half million dollars in 1931 and was approximately two million dollars in 1930. Coming at this time this unquestionably has contributed much to the welfare of the region. During 1929, the latest available year, the pay roll on the Hetch Hetchy project was 87.8 percent of the entire State pay roll for tunneling work that was insured by insurance carriers.

Excavation progress as of May 1, 1932, is shown in Table 1.

The number of employees in the tunneling classification during 1931 averaged 1,520 three-hundred-day workers; this classification represents approximately 80 percent of the total number of persons employed at the various camps. The remaining 20 percent employed were in other classifications on the surface and are not included in this report.

The degree of work carried out in the different headings has varied with conditions. A working day of 8 hours has been in effect at this enterprise and material has been hauled on all three shifts normally worked underground. The average tunnel crew in each heading for one shift consists of one superintendent, who looks after the whole camp, one shift boss, one mucking machine operator, one motorman, one nipper, four miners, three chuck tenders, four muckers, one skip tender, one station tender, one pumpman, and one fire boss. In addition, there may be other miners engaged in retimbering, two or more men guniting in sections, and men who work on any shift, such as a trackman, a pipeman, and a track foreman. A night walker replaces the superintendent on the afternoon and night shifts. Members of the engineering staff are constantly employed underground in some section or other.

Table 1.- Main aqueduct, Coast Range division excavation progress, May 1, 1932

Heading		Station, April 1	Station, May 1	Progress for month	Progress to date	Total remaining
Tesla	173+45					
	West	312+49	312+49	-	13,904	-
	(East	312+49	312+49	-	9,406	
Thomas	(					
	(406+55					
	(West	494+98	498+94	396	9,239)	8,311
					)	
	(East	584+11	579+36	475	4,894)	
Mitchell	(					
	(628+30					
	(West	696+74	698+58	184	7,028)	10,965
					)	
	(East	807+43	804+22	321	9,973)	
Mocho	(					
	(903+95					
	(West	979+76	982+17	241	7,822)	179
					)	
	(East	986+21	983+96	225	7,302)	
Valle	(					
	(1056+98					
	(West	1146+98	1148+89	191	9,191)	4,579
					)	
	(East	1196+66	1194+68	198	13,102)	
Indian Creek	(1325+70					
	(West	1356+93	1356+93	-	3,123)	997
					)	
	East)	1366+90	1366+90	-	13,020)	
	)					
Alameda Creek	1497+10)					
	1528+29)					
	West)	1616+35	1616+35	-	8,806	
	East)	1616+35	1616+35	-	9,386	
Irvington	1710+21					
Total				2,231	126,196	25,031
					151,227	
Top drift, Indian W. (1365+82)		1360+11	1361+86	175	-	-

Surface Plant and Equipment

Slow-burning wood construction throughout for headframes is used at all shafts. Fire protection is provided at these locations by hose, hydrant, and sprinkling systems. Chemical extinguishers are also provided. No regular fire drill is held.

Gasoline locomotives are used on the surface for handling muck cars. Double-drum, electrically driven hoisting engines with a maximum speed of 600 feet per minute are used; overwind and overspeed equipment are not provided. The surface electric voltage is 440 volts a.c.; the energy is obtained from the City-owned power plant, transmitted at 22,000 volts, and stepped down to 440 volts by transformer banks efficiently installed near shaft portals. These enclosures are kept locked. Electricity is used throughout for surface lighting.

A washhouse is provided at camps, with combination shower house and hot and cold water, together with lavatories and sanitary toilets.

The workmen are housed in 5-man bunk houses. Drinking water is supplied from springs and is regularly analyzed. Cookhouses are efficiently maintained at all camps.

The men are checked into and out of the tunnels by means of identification tags taken from a rack by the men on each shift, and time cards which are taken from a rack and marked by shift bosses. Both identification tags and time cards are returned at the end of each shift.

Underground Equipment and Haulage

Man-cages of Joshua Hendy design are used in the shafts. These cages are equipped with safety devices, and drop tests are performed regularly at 2-week intervals; the cages have steel-bonnet protection and are cleaned and oiled daily.

Ladders and safety gates are maintained in the shafts, which are efficiently concrete lined. The ropes are inspected at regular intervals.

Rails of 30, 40, and 50-pound weight are used for the underground haulage system, which has a track gage of 24 inches.

Forty-one storage-battery locomotives of General Electric, Westinghouse, and Mancha manufacture are used underground. Twenty-seven of these are of permissible types operating at 80 volts for use in the tunnels known to give off explosive gas. Eighteen are of 5-ton weight and 23 of 4-ton weight.

The cars in use are of 2-yard Koppel-steel and 3-yard Western dump - wood body, designs. There are no grade hazards.

The tunnels are not lighted with incandescent lights in the gassy sections, as this is known to be a serious potential explosion hazard.

Separate man-trips are provided and men are not permitted to ride on loaded trips; workmen are not permitted to ride on bumpers, nor to make flying switches. Tail lights of the permissible electric storage battery type are used on all trips.

Explosionproof motors of permissible types are used for pumping units in some headings where methane gas is present; other pumping units in the headings are of duplex design and are compressed-air driven. All underground electric equipment is operated in intake air.

Compressed air operated mechanical loaders are used, one in each heading, and a spare is carried for contingencies. The loaders are of Conway and Myers-Whaley manufacture. There have been no fatal accidents directly assignable to these loaders. The number of men on a loader crew varies, but the usual heading crew will consist of 12 men.

All mechanical electrical equipment is inspected daily and an effort made to maintain the permissibility of the permissible equipment.

The Coast Range tunnels have been timbered throughout, and a portion of timber has been supplanted in places with guniting. The type of timbering has varied, but the typical set is a 6-segment arch with plumb posts. The distance between sets depends on the length of the round broken and the nature of the ground encountered. Systematic timbering rules are printed and a continual effort is made to carry out the orders.

Explosives

The use of explosives is one of the major means of operation in tunnel driving. From the point of view of safety, it is probable that unsafe blasting practices offer the greatest hazards in the average tunnel for large groups of the tunnel workmen. The use of explosives on the Hetch Hetchy project represents a welcome transition from the unsafe crowding practices usually obtaining in contracting work with fuse and caps, to the up-to-date, much safer method of using permissible explosives and electric blasting. There is probably no better example of what can be accomplished in safeguarding blasting practice than will be found on the Hetch Hetchy project.

Between the years 1920 and 1923 explosives with fuse and detonators caused four explosions, which cost the lives of 11 persons, and injured 10 others; these explosions occurred during the driving of approximately 85,000 feet of tunnel. Following this period, electric blasting was adopted, and but one explosive accident has occurred, one life being lost while tamping a primer. During this latter period, and up to May 1, 1932, there have been 209,859 feet of tunnel driven. Unquestionably, the substitution of electric blasting has been largely responsible for the great improvement in safety achieved in the latter period.

The number of explosive accidents in this tunnel work not involving a loss of life is not known. The use of the inert primer[11] in tunneling operations would unquestionably aid in the prevention of explosives accidents in connection with missed shots, striking primers, removing charges, transportation, etc., - the causes of most explosives accidents in tunneling and metal-mine operations.

Gelatin, Colites, and Herco-Gel explosives have been used in these operations since 1930. Electric blasting caps of No. 8 strength are employed.

The eight surface magazines at the respective camps are constructed to conform to California laws of distances and are bulletproof.

The explosives are hauled into the tunnels by the motorman; 2-compartment, insulated powder cars are provided for the explosives and detonators, which are kept separate.

A maximum of 100 pounds of explosive is stored underground in locked wooden boxes; this explosive is for single-shot plugging done with permissible explosive and permissible single-shot blasting units. Explosive sufficient for a round of about 40 holes is brought into a tunnel direct from the surface.

Explosives and detonators are not handled by the same man at the same time. The miners and shift boss load the holes. Cartridges are used and air spacing is guarded against. The cartridges are slit and the explosives carefully rammed. Clay stemming is used and a wooden-type bar is used in tamping.

Rounds of 20 to 40 holes are drilled with compressed-air drills using water. Four to seven sticks (1-1/8 by 8 inches) of permissible explosive are used per hole. From 5 to 9 feet are "pulled," depending on the ground.

Shooting is done by a fire boss who has satisfied the Industrial Accident Commission as to his ability to handle gassy conditions; one fire boss is employed on each shift. From 1 to 40 shots are fired at one time, delay-action exploders being used.

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[11] - Manning, R. I. C., and Soule, Thomas, Electrical Blasting Practice at the Morenci mines of the Phelps Dodge Corporation, Morenci, Arizona: The Explosives Eng., June, 1931, and July, 1931.

Power blasting is used for the main rounds, a special blasting switch[12] being employed for this purpose. The locked switch is operated by the fire boss from the shaft crosscuts with all men removed about 5,000 feet or more from the face. Permissible single-shot blasting units operated by the fire boss are used for plugging.

Misfires were common prior to the adoption of electric blasting, and are assigned as the cause of all previous explosives accidents, costing 11 lives; no fatalities have been caused by misfires since the adoption of electric blasting, though two nonfatal accidents occurred when unexploded primers used for plugging were struck when picking for posts. Inert primers very likely would prevent this type of accident.

In case of known misfires, which are examined and reported, a new primer is used and the hole is again fired. The legs of all electric detonators are short-circuited and the "short" is removed before loading. No record of misfires is available, but it is known that they are rare and appear to be a result of series-blasting for plug shots.

Electricity Underground

All high-tension electrical energy is transmitted underground by armored cables at 2,200 volts a.c. The low-tension voltage is 110 and 440 volts a.c.; no direct current is used underground except at storage battery charging stations. The motor-generator sets are placed on separate air splits, in concrete sections. Transformers are set up in concrete stations, and the fire hazard is kept at a minimum.

Wiring is carried in conduit and separate power switches and circuits are used. Electricity, except under permissible conditions, is kept out of all gassy tunnels, and incandescent lighting is used at the shaft stations only in strictly fresh air.

The electrical system and equipment are inspected monthly by the electrical engineers and a report is made to the construction engineer. There have been no electrical contact accidents which have resulted fatally or seriously.

GENERAL SAFETY PRACTICES AND ACCIDENT PREVENTION

During the sinking of the Mocho shaft in 1928, it early became evident that the hazards from the explosive gas methane and the toxic hydrogen sulphide gas should receive serious consideration; explosions of methane have been by no means uncommon in tunnel operations[13] in the Coast Range Mountains when a certain formation, the Franciscan, is penetrated.

Adequate ventilation of workings has been given a prominent place in the activities of the Coast Range division, and this phase of operation of these tunnels should be of value in indicating safe yet efficient ventilation and operating measures in future tunnel driving in gassy strata. The possibility of occurrence of methane is not to be considered a "chance" hazard in any Coast Range tunneling operations in the Franciscan or Cretaceous formations; it should be recognized as a "real" or at least a probable hazard in this district by the State, insurance carrier, contracting party and contractor, and prior to engaging in tunneling operations in this region steps should be taken to provide suitable types of equipment to avert hazards before explosions or fires occur.

Ventilation and Gas

Ventilation of the Coast Range tunnels is by means of Roots rotary-type, positivepressure blowers of three sizes - 5, 5-1/2, and 7 - installed on the surface in fireproof,[14] galvanized-iron buildings placed 30 to 50 feet from the shaft openings. Reserve motive power is available.

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[12] — See footnote 10.

[13] — Harrington, D., Work cited, p. 9, Progress in Metal-Mine Ventilation in 1930: Inf. Circ. 6469, Bureau of Mines, 1931, p. 9.

Metal pipe of 16 gage and 24-inch diameter is used, and the blowers are operated as suction units. Prior to operating on an exhaust system with the relatively high pressures obtainable with this equipment, it was believed that the pipes would collapse; however, as precautionary measures required an exhaust system, tests[15] were made with a stiffener band placed on the outside of the metal tubing to prevent collapse or deformation. These bands have accomplished this purpose. Obviously, if there is no deformation there could be no collapse. To insure against collapse, pressure readings are taken with a manometer and a record of them is kept.

In the Indian Creek tunnel 6,078 cubic feet of air is circulated through 13,500 feet of 24-inch pipe at a vacuum of 1.85 pounds per square inch at the fan on suction; this was not believed possible of achievement until it was actually done.

If there are any interruptions in the running of the fan at the gassy tunnels, notification is made from the surface and the men are sent out, or if the fire boss or shift boss first notes the interruption he orders the men out of the mine.

Under the heading of "tunnel ventilation" Harrington[16] discusses the ventilation of the Coast Range division of the Hetch Hetchy project and the accident-prevention measures which are being taken.

It has been frequently found, not only in the Coast Range tunnels of the Hetch Hetchy project, but also in other tunnels in this vicinity, that methane gas may be liberated suddenly; it is a constant hazard. In one tunnel alone, 116,900 cubic feet of pure methane was liberated in 24 hours in some 9,783 linear feet of tunnel.[17]

To provide adequate protection and prevent the accumulations of dangerous quantities of explosive gas, certified fire bosses are employed on each shift. Permissible flame safety lamps are kept in each heading, but on account of the danger always accompanying the use of flame safety lamps if they are not properly assembled and handled, their number is kept at a minimum.

To inspect for gas, which is done continuously during the shift, the fire bosses use U.C.C. methane indicators. The superiority and safety of these devices for accurate and efficient inspection has been emphatically demonstrated in connection with the driving and handling of these tunnels. A detailed report is made by each fire boss at the close of each shift; a copy is sent to the city engineer's office and a copy to the State Industrial Accident Commission.

It is probable that methane indicators find their largest use in the construction field, and that the cost items for them in that industry would be high as compared with the same items in the mining industry; this also applies to permissible electric cap lamps.

The cost of maintaining 12 methane indicators in operation during 18 months was $980 for repairs, $2,208 for 830 filaments, and $468 for battery cost, replacement, and overhaul - in all, $3,656.

These indicators have been in constant use on the Hetch Hetchy project since May, 1930, at each camp. Fire bosses trained in their use patrol the working places on each shift and record readings at the headings at least hourly. The indicator quickly notes percentages of methane from 0.10 percent to explosive mixtures.

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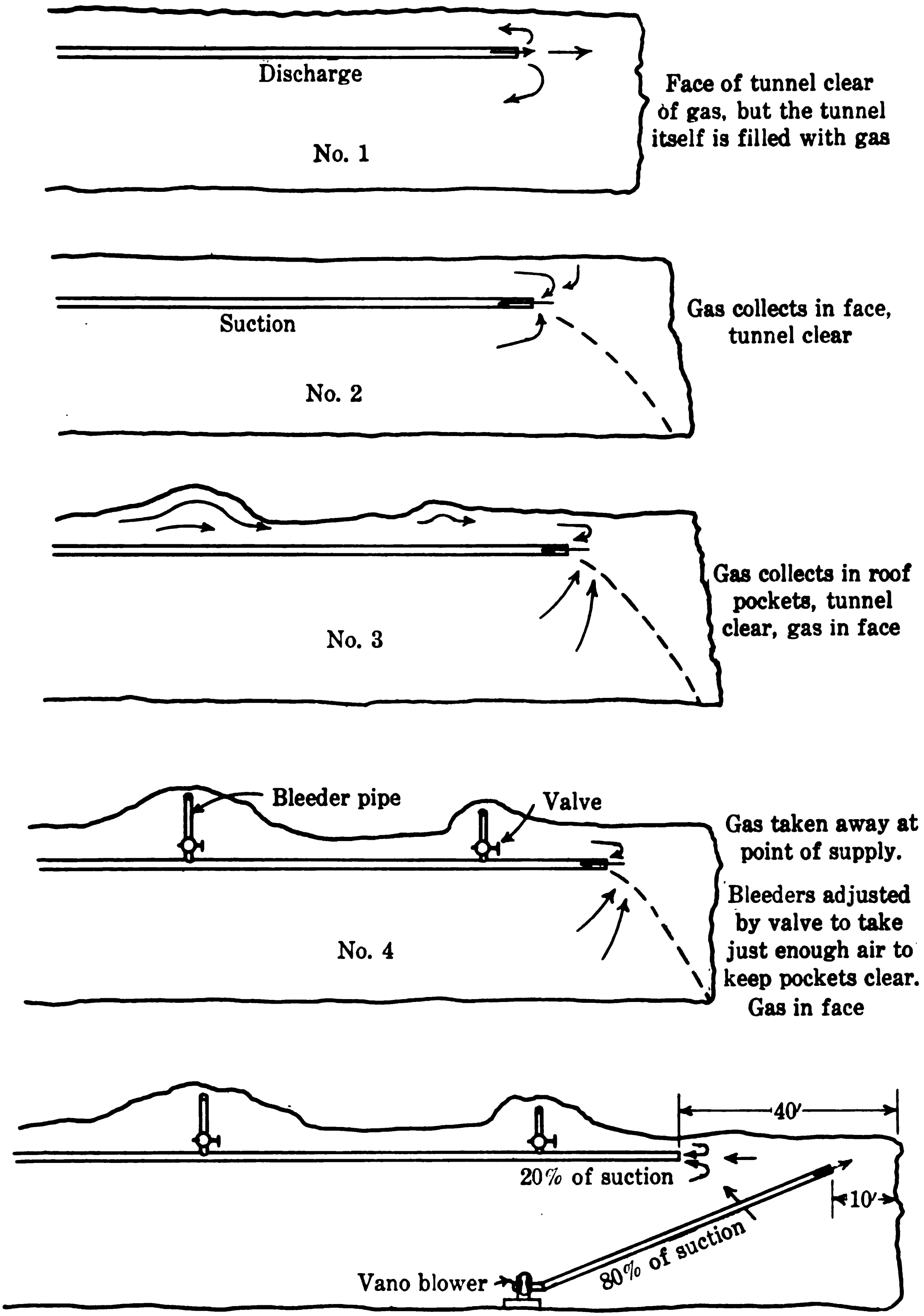
[14] - See footnote 10.

[15] - See footnote 10.

[16] - Harrington, D., Work cited, pp. 5-11.

[17] - Ash, S. H. and Rankin, J. H., Work cited, p. 25.


Discharge
No. 1
Face of tunnel clear of gas, but the tunnel itself is filled with gas
Suction
No. 2
Gas collects in face, tunnel clear
No. 3
Gas collects in roof pockets, tunnel clear, gas in face
Bleeder pipe
Valve
No. 4
Gas taken away at point of supply.
Bleeders adjusted by valve to take just enough air to keep pockets clear. Gas in face
40′
20% of suction
10′
80% of suction
Vano blower

Ideal condition: 20% of suction from tunnel, 80% through blower to clear face. Pockets are cleared through bleeder pipes

Figure 1.- Method of using blower pipes in tunnel ventilation.

With the U.C.C. indicator it is possible quickly to determine the percentage of methane along the length of the tunnel and readily define the depth of gas strata and percentage curve. This would be impossible with a flame safety lamp, a slow and questionable determination with a Burrell methane indicator, and an unduly costly and delayed process by any sampling method.

The average life of filaments depends to a large extent on the skill of the operator, as well as on the percentages of gas encountered. Early experience was 79 to 82 hours use per filament, but this has been increased considerably since the gases have been piped to the main exhaust line.

The zero point of the U.C.C. indicator must be checked at least every hour in fresh air, as it is found to vary much at times if held continually in gas-impregnated air. The checking can be done by going to the surface, or where compressed air is in use, by placing the instrument in fresh air from the compressed air line at a favorable point.

It was found that special attention must be paid to the batteries to get the best results. Charging was never done at a greater rate than 1 ampere, as it was found that in this way the cells do not overheat and yet secure the full benefit of the charge. The charging time averaged about 8 hours, and about once a week an overcharge was given of about 16 hours at not more than 3/4 ampere-hour. The batteries should be given a water wash and a new solution at least every three months if in constant use. The solution in both cells was checked every day to see that it was not only at the same level but also gave the same reading. With careful treatment of the terminals, little trouble with the batteries was experienced after starting to handle them as described, although previously trouble was more or less constantly experienced.

Experience and study with the U.C.C. detector indicate that it can fill a valuable place in practical gas analysis and in accident prevention in mines and tunnels. However, the following improvements appear to be desirable: A smaller gas chamber around the filament, a better method of zero adjustment, a simplified battery, and adaptability to any permissible electric cap-lamp battery.

The sequence of ventilation changes that were made in the tunnel ventilation is shown in Figure 1.

The amount of fresh air intaking at the different tunnels varies with conditions as regards gas and temperatures and has ranged from 6,000 to 30,000 cubic feet per minute.

Samples of mine air are collected from time to time and analyzed by the United States Bureau of Mines. The results are studied and desirable changes made in ventilation practice.

Lighting in the gassy tunnels is by means of Edison permissible cap lamps. Incandescent lamps in these gassy tunnels are used at the shaft landings only in fresh air. Probably most of the methane explosions that have occurred in the tunneling operations in gassy strata in California, including Hetch Hetchy, are the result of some failure in the incandescent lighting system used in tunnel illumination; these systems cannot be made foolproof. The permissible electric cap lamps remove the explosion hazard and give dependable, effective lighting, and they should be more generally used in all kinds of underground mining operations.[18]

The following data (Table 2) relative to the costs of such a lighting system are of interest. Aside from the safety factor, which was the determining influence in their selection in this instance, they are efficient and tend to reduce accidents. The information in Table 2 covers the use of Edison permissible cap lamps from July, 1930, to April 15, 1932. The scattered locations make the item of attendant's time unusually high as it has to be divided between 8 camps for less than a total of 1,000 lamps. In most situations an attendant's time would not be wholly occupied with the lamps, or he could handle a larger number. The compilation is at least fairly reliable, is conservative, and represents maximum rather than minimum figures as to costs.

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[18] - See footnote 10.

Table 2.- Costs of operating Edison electric cap lamps at the Hetch Hetchy project, July 1, 1930, to April 15, 1932

	Total cost	Unit cost, cents per man-day
979 Edison cap lamps complete, Model H	$13,216	-
20 extra batteries	213	-
8 charging racks	1,120	-
8 Tungar chargers	440	-
Total equipment	14,989	1.98
Battery repair parts	1,087	-
Lamp repair parts	6,328	-
9046 bulbs	1,536	-
Total repairs	8,951	1.18
Lamp attendants and electrician's time	25,000	3.31
Power	125	0.016
Grand total	49,065	6.494
Man-days of labor performed		755,664

In addition to the use of permissible electric cap lamps a storage-battery flood light[19] was developed by the city engineer's office and is used at the loading machines.

At irregular intervals the men entering the underground workings are searched for matches and smokers' articles; any one found with such articles is disciplined by discharge. A form is used for recording the results of the search. The California mining laws do not define such an offense as a misdemeanor.

An assistant engineer of the project is employed as a safety engineer, whose duty it is to inspect the tunnels, report concerning the safety conditions, and make suggestions for improvements to the construction engineer. In addition to a verbal report an inspection report form, Figure 2, is filled out.

Supervision

There is probably no factor in safeguarding property and the workmen in any industry of more importance than efficient supervision in a safe working place. Without it there can be no effective safety program and certainly no efficient operation.

Undoubtedly no type of construction work requires more adequate and efficient supervision than tunneling operations; this fact has been kept in the foreground on this project, and an average of only about 12 men is employed under each face boss. The face boss spends most of his time at the face and is not hurried in any visits. Whenever orders are given it is insisted that they be carried out.

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[19] See footnote 10.

INSPECTION REPORT

CAMP ____________________ Date _________________

Tunnel heading ________________

Kind of ground ____

Timber alinement ____

State of timber ____

Timber alinement ____

Blower pipe ____

Gas condition ____

Equipment

Air-leakage 4-inch pipe, receivers __________________________________

Line oilers ____

Safety lamps ____

Coppus blowers ____

Fire protection

(Camp and tunnel)

Hose and racks ____

Old timber refuse ____

Sanitation

Eating place canvas ____

Miscellaneous

Man cages __________________ Tests __________________________

Pumps ___________ too many ___________ too few

____
Assistant Engineer

Figure 2.- Inspection report form

When an entire week passes without any industrial accidents in the tunnel work, a special chicken dinner is served to the entire camp; several chicken dinners have been earned since this system was inaugurated.

Special safety orders[20] issued by the Industrial Accident Commission, other working rules, and posted notices are put into effect as is found to be necessary.

Miscellaneous Hazards

To minimize the fire hazard, carbon dioxide extinguishers are provided for all electrical equipment. Other extinguishers are placed at points of hazard. Galvanized-iron buildings only are used on the surface. Oil used underground is stored in concrete stations.

The shafts are lined with concrete and all shaft stations are of concrete construction.

The ventilation is of such nature that direction of air flow is reversible; the system has always been maintained in this condition.

Fire-protection pipe lines are laid throughout the tunnels with water taps at 250- to 500-foot intervals. Three hose stations are maintained underground for each shaft; 2-inch hose in 100-foot lengths, one carbon dioxide fire extinguisher, and six soda extinguishers are provided at these stations. Two-inch water lines and fire hose are provided at each heading and at the shaft crosscut.

The flood hazard in the Coast Range division has been efficiently guarded against in the areas where quicksand and water have presented that hazard to a limited, but for a time, troublesome degree.

The exhaust system of ventilation, together with fairly high rock temperature and high relative humidity, makes working conditions somewhat uncomfortable and means are being taken to protect against high wet-bulb temperatures in lining operations.

To prevent head and foot injuries and to minimize the severity of such injuries as do occur, the men are furnished with hats for head protection and with safety shoes to protect toes and ankles.

Mine-Rescue and First-Aid Practices

On June 8, 1930, an explosion[21] due to methane in the Upper Alameda Creek Tunnel of the old Spring Valley system caused the death of seven persons. Events following this disaster emphasized the importance and necessity of having a sufficient number of persons trained in the use of mine-rescue oxygen breathing apparatus in the Coast Range division of tunnels operating in the same geological strata. Accordingly, a mine-rescue station was equipped at the Hetch Hetchy project, and mine-rescue training began on June 21, 1930, under the supervision of the United States Bureau of Mines. The efficiency of the men trained at this project in this work has been demonstrated in an actual emergency, and the work has been consistently maintained.

The management of this project has recognized the fact that the chance of injury is usually minimized for a man trained in first aid, as he has become "safety conscious." At the request of the city engineer, in March 1931 a program was started to train every workman on the project and to maintain this status. Contests in this work are held from time to time between crews from the different communities, and training is kept in effect.

A mine-rescue station is maintained at Livermore, as it is central. Here are 10 sets of Gibbs oxygen breathing apparatus, an oxygen pump, an inhaler-type oxygen reviving device,

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[20] - See footnote 8.

[21] - See footnote 10.

120 regenerator charges in stock, and 12 to 18 oxygen tanks. In addition, there are 33 gas masks and a stock of 75 canisters, all in working condition. The apparatus is used monthly and kept in condition for wearing.

The apparatus is in charge of A. J. Wehner, safety engineer, and S. M. Jarrett, first-aid and mine-rescue instructor and relief fire boss.

That the goal of 100 percent first aid training is in sight can be realized when it is recognized that 1,200 persons have been trained in first aid; in addition, 120 have been instructed in mine rescue and 46 in advanced mine rescue and recovery work, and both groups have been certified by the U.S. Bureau of Mines since June 1930. Some of the camps are 100 percent trained in first aid. This group of persons is the largest so trained in any individual mining or tunneling enterprise in California.

In addition to the first-aid or mine rescue certificate furnished by the United States Bureau of Mines, each person completing the training work is given a certificate issued by the project.

Completely equipped canisters, stretchers, and first-aid kits are maintained underground at each tunnel. Similar equipment, including stretchers, blankets, and other supplies is kept in the first-aid training rooms maintained on the surface at each camp. The nearest hospital is at Livermore, which is 9 to 19 miles distant.

Safety Organization

A safety organization is maintained and directed by the construction engineer, assisted by the safety engineer; monthly discussions are held in which the tunnel foremen and fire bosses participate.

A safety committee functions at each tunnel; its duty is not only to suggest safety ideas, but to assist in carrying them out. This committee consists of the camp superintendent and three workmen, the safety inspector acting as secretary. A report of the serious accidents investigated by this committee is made as shown in Figure 3.

METHOD OF REPORTING ACCIDENTS

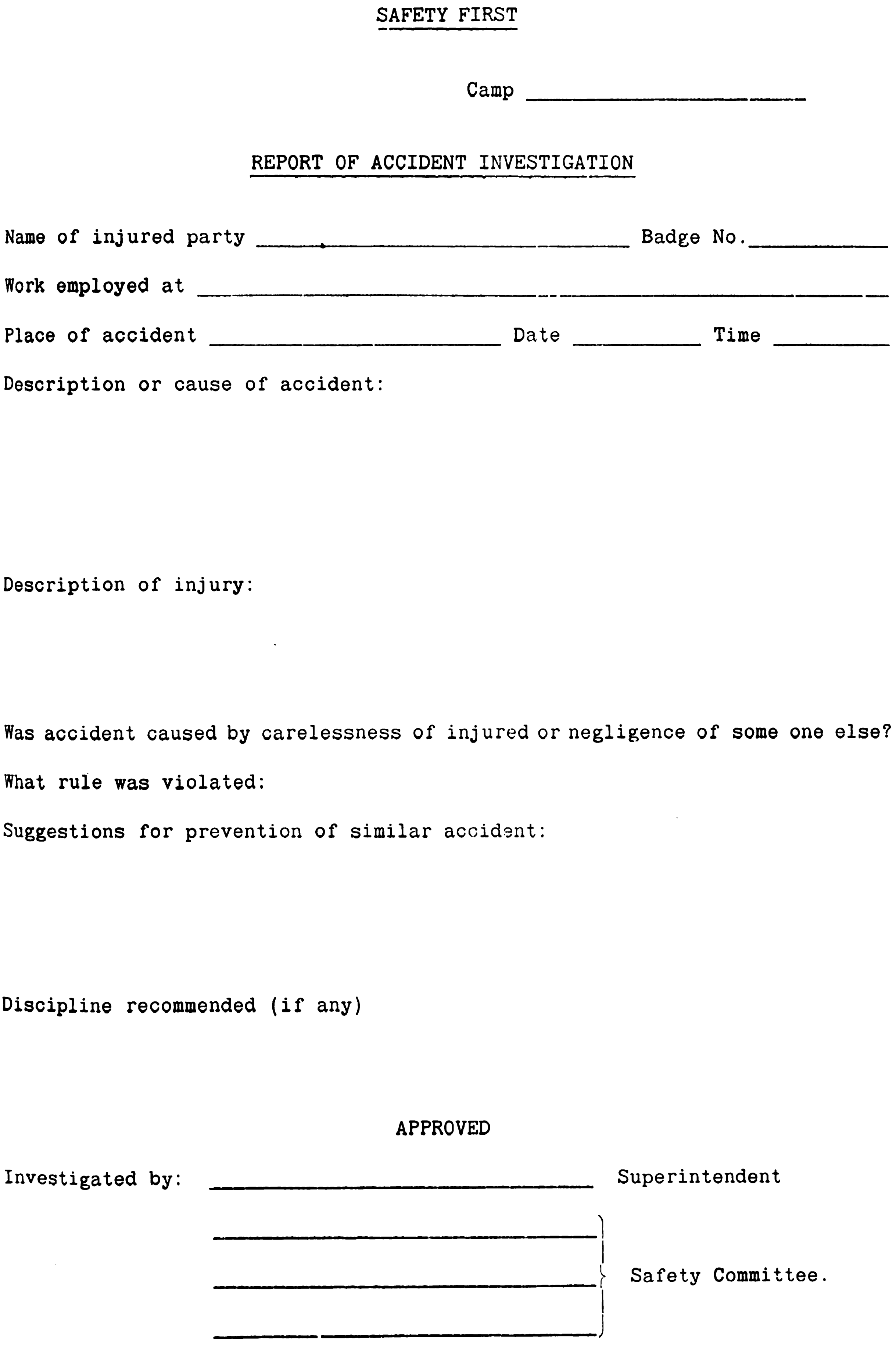
All accidents are reported by the fire bosses and timekeepers to the safety engineer, who in turn refers them to the construction engineer through the chief clerk. A special clerk in the Livermore office handles all accident claims and submits them to the insurance carrier.

At the Hetch Hetchy project the city provides the medical care, while the compensation insurance item is carried by the State Compensation Insurance Fund.

If the case is one for a hospital or if medical treatment is required the injured person is given a certificate of entry to the hospital (fig. 4) by the clerk. When the workman is ready for work a discharge slip (fig. 5) is given to him which must be presented to the timekeeper, who assigns him to work. These slips, including the form (fig. 6) filled out by the attending doctor, are given to the clerk who attends to the compensation insurance items. Such items are reported on suitable forms.

MEDICAL SERVICE

For many years the city has maintained a hospital equipped to handle all cases, both medical and industrial. Until May 1930 this hospital was at Groveland, near the foothill division of the tunnels. With the object of having a hospital nearer and in the center of operations of the Coast Range division, the city's Livermore hospital was acquired and opened for service on August 25, 1930.



SAFETY FIRST

Camp ______________________

REPORT OF ACCIDENT INVESTIGATION

Name of injured party ______________________________ Badge No.___________

Work employed at ____

Place of accident _______________________ Date __________ Time _________

Description or cause of accident:

Description of injury:

Was accident caused by carelessness of injured or negligence of some one else?

What rule was violated:

Suggestions for prevention of similar accident:

Discipline recommended (if any)

APPROVED

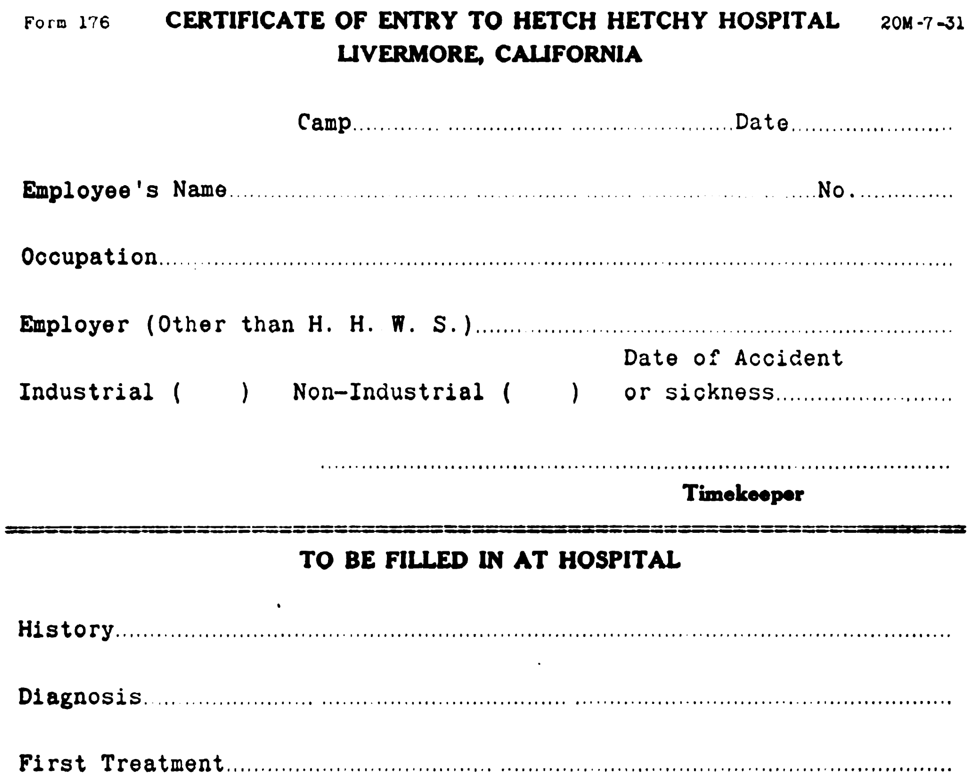
Investigated by: ______________________________ Superintendent

____

______________________________ } Safety Committee.

____

Figure 3.- Accident investigation report form.



Form 176 **CERTIFICATE OF ENTRY TO HETCH HETCHY HOSPITAL** 20M-7-31

LIVERMORE, CALIFORNIA

Camp...Date.......................

Employee's Name...No..............

Occupation...

Employer (Other than H. H. W. S.)...

Industrial ( ) Non-Industrial ( ) Date of Accident or sickness.........................

....

Timekeeper

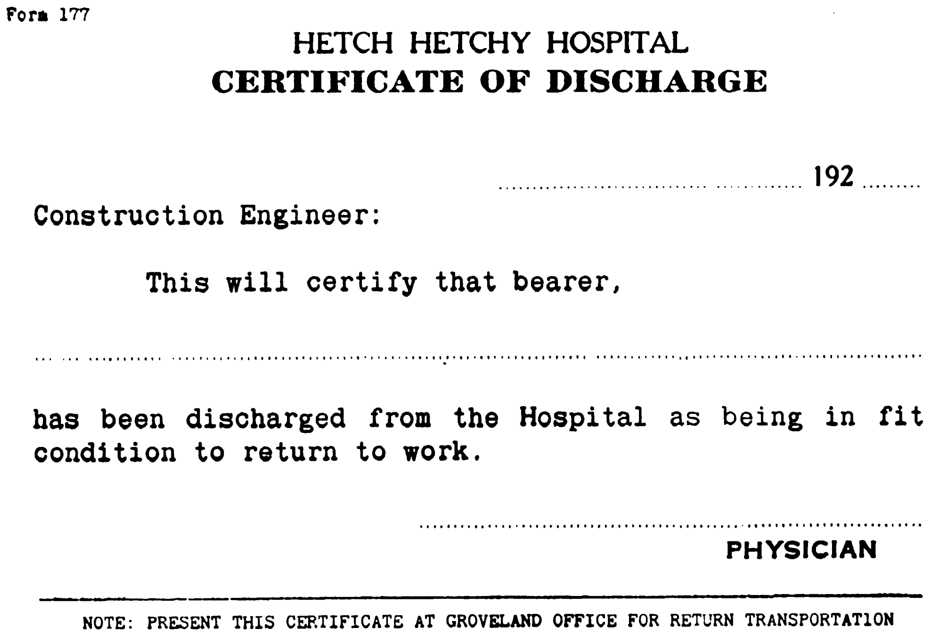
TO BE FILLED IN AT HOSPITAL

History...

Diagnosis..

First Treatment...

Figure 4.-Certificate of entry to hospital.



Form 177

HETCH HETCHY HOSPITAL

CERTIFICATE OF DISCHARGE

.... 192 ....

Construction Engineer:

This will certify that bearer,

....

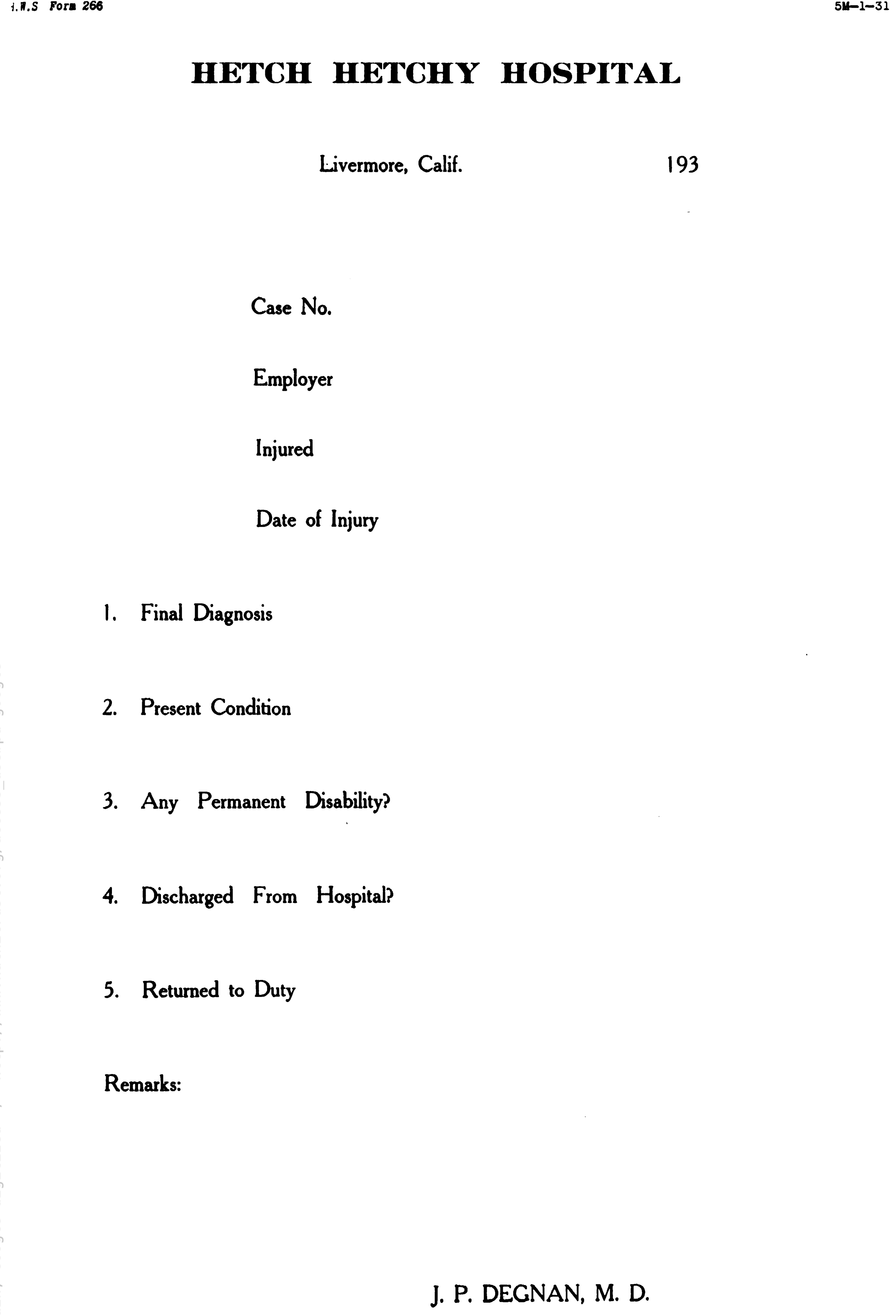
has been discharged from the Hospital as being in fit condition to return to work.

....

PHYSICIAN

NOTE: PRESENT THIS CERTIFICATE AT GROVELAND OFFICE FOR RETURN TRANSPORTATION

Figure 5.- Certificate of discharge from hospital.



.W.S Form 266 5M—1—31

HETCH HETCHY HOSPITAL

Livermore, Calif. 193

Case No.

Employer

Injured

Date of Injury

1. Final Diagnosis

2. Present Condition

3. Any Permanent Disability?

4. Discharged From Hospital?

5. Returned to Duty

Remarks:

J. P. DEGNAN, M. D.

Figure 6.- Form filled out by attending physician

The main hospital building is 187 feet by 41 feet and contains 31 beds and full equipment. The members of the hospital staff, Dr. John P. Degnan in charge and eight assistants, are subject to call at all times. Three cottages are provided for the hospital staff.

All employees are subject to physical examination at the hospital before entering the service of the city, and each employee is assessed $1 per month for medical service.

Ambulance service is provided, subject to call day or night, for transportation between the eight camps and the hospital.